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Qualitative Observations and Conclusions From Idealised Small Scale Straw Burning Trials

by

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SUMMARY

During June 1984, 23 trial straw burns were carried out on a disused airfield near Bedford, in conjunction with Warren-Spring Laboratory and Silsoe Agricultural College. The straw was spread over an area of concrete and burned in various ways. It was impossible to obtain any conclusive results from these tests, but they did serve to broadly indicate good and bad burning conditions and burning methods. The main objective of the work was to test instruments and develop techniques for use in the full-scale field experiments in August 1984.

The work confirmed that a wind of force 3 was about the highest in which burning could be carried out safely. Burning against the wind gave marginally cleaner smoke, although the burn time was often about three times that taken when burning with the wind. The lift off of the smoke plume from the ground was highly dependent upon wind speed. It was not clear which burn types gave the most and least smuts.

1. Introduction

In order to try to curtail smoke and smut pollution from straw fires the National Farmers Union have issued a straw burning code. This code has been produced using evidence from past experience, but does not have an objective basis. Consequently clauses such as "suitable weather conditions" arise without any qualification.

There is a need to quantify more precisely the best way and the most suitable weather conditions in which to burn straw. For this reason a thorough study of straw fires will be made in August 1984. As a preliminary experiment to test equipment, and possibly isolate some good and bad burning methods, a few small scale experiments were carried out on a disused airfield near Bedford in June 1984.

Two large round bales of straw weighing 0.67 tonnes each were spread over an area of concrete 30 metres x 30 metres. Sampling instruments for smoke and smuts were placed down wind, and wind measurements made continuously throughout each experiment. Routine hourly observations were made about 3 kilometres away at RAE Thurleigh and some soundings of the atmosphere were made about 10 kilometres away at Cardington.

2. Straw Treatments and Burn Direction

The following combinations of treatment and burn direction were tried:-

i) Spread straw with the wind.

ii) Spread straw against the wind.

iii) Spread straw across the wind.

iv) Along the swathe with the wind.

v) Along the swathe against the wind.

vi) Across the swathe with the wind.

vii) Straw kept in bale.

Four burns of all treatments except iii) and vii) were carried out, for which there were two burns and one burn respectively.

3. Burn Rate

The speed at which the straw burned was primarily dependent upon whether the burn was made with, against or across the wind, although there was also a small difference in burn speed between swathed and spread straw, all other things being equal. The treatments can be ranked as follows, starting with the fastest burns:-

i) Spread straw with the wind.)
) Very similar speeds.
ii) Across the swathe with the wind.)
iii) Along the swathe with the wind.)

iv) Spread straw across the wind.)
v) Spread straw against the wind.) Very similar speeds.
vi) Along the swathe against the wind.)

As the wind speed increases so the time difference between burning with and against the wind widens. At very low wind speeds (less than 1.5 metres per second) there is virtually no difference in burn rate, largely due to variability in wind direction in such conditions. With the wind at 2-2.5 metres per second the difference in burn time is about a factor of 2 (14-28 minutes), and at around 5 metres per second the factor is about 5 (8-40 minutes).

4. Flame Characteristics

Flames are higher in burns with the wind than when the burn is against the wind. For swathes the respective flame heights are about 1.5 and 0.5 metres in a 2-3 metres per second wind, but at higher wind speeds 3 metre high flames are possible when burning with the wind. When the straw is spread the flames are less vigorous, rarely exceeding 1 metre high, and often only 0.2 - 0.3 metres high when burning against a strong wind.

The width of the flame front was normally about 0.1 - 0.2 metres when burning against the wind, depending on wind speed, and from 0.2 metres wide for spread straw in low wind speeds with the wind to 15 - 20 metres for straw in swathes in high wind speeds, specially when burning across the swathe.

5. Smoke Characteristics

The smoke varied quite markedly in both colour and density, even within the same burn. The smoke usually started as a dense brown or black colour, but often became clearer as the burn proceeded. In the latter stages, dense grey smoke from smouldering material usually became increasingly prevalent, and once the flames had virtually died out was the sole smoke type.

If the wind ever became very light (less than 0.5 metres per second) the smoke became noticeably more dense, but as it would lift straight off the ground in such instances, ground level nuisance was at a minimum. Also during wind direction changes the plumes seemed to become more dense for a short time.

During the main phase of the burn, there was not a noticeable difference in the smoke density or colour when burning with or against the wind. However towards the end, as the flames die away, the quantity and density of grey smoke from burning with the wind was significantly greater than when back burning. This difference occurred especially when there was a good breeze blowing (greater than 3 metres per second), because in such cases burning with the wind would cause incomplete combustion of much of the straw (especially if damp), whilst the slow progress of the flame front during back burning would allow more complete combustion.

There was some evidence that smoke from swathe burning was cleaner than that from spread straw burning. This could be the result of better airflow around swathes causing hotter and more complete combustion, and if so, may not be so noticeable in a field where stubble would allow better airflow around spread straw.

The dark smoke produced by complete combustion at the flame front was considerably more buoyant than the grey smoke from areas of smouldering. Grey smoke had to have virtually no wind in order to become clear of the ground, whereas brown smoke eventually cleared the ground even when the wind was at 4-5 metres per second, although it may travel for up to 50 metres before lifting off. When the fire is burning fiercely (in a good breeze) the updraught may be 3-4 metres per second, but is about 1-2 metres per second in light winds.

In the main stage of the burn, especially when burning with the wind, the thick grey smoke which forms behind the flame front tends to become drawn into the hot plume and lifted off the ground. This happens to a lesser extent in back burning when the wind is light and the weak indraughts (of about 0.5-1 metre per second) are able to operate. In stronger winds two distinct plumes are more likely to form when back burning, with the grey smoke permanently hugging the ground, and the brown smoke lifting off.

In these small scale trials the smoke usually dispersed within 250 metres of the burn area, before the smoke plume had attained its maximum possible height. Hence it was rare to see the plume rise to more than about 80 metres, although at this stage it clearly had not levelled out.

6. Smuts

Smuts can be defined as those particles which can be seen with the unaided eye and that have a definite fall velocity relative to the smoke plume. Fall velocities in the region 0.1 - 0.5 metres per second were observed. Visually it was impossible to tell which burn types were the least and most smutty. Certainly the largest smuts (up to 0.3 metres long) were observed to come from the most vigorous burns. Smuts could be seen falling to the ground at all distances up to at least 75 metres from all the burns, and were apparently quite evenly spread over that distance.

A particularly efficient means of getting charred material airborne was observed in vortices. The vortices tend to occur in light wind conditions as the fire is dying down and can lift large quantities of material up into the smoke plume.

A common practice of farmers is to bale a 25 metre width of straw and place the bales within the burn area before burning. As a final experiment at Bedford two bales of straw were burnt. The bales were seen to give off a higher concentration of smuts than was seen in any of the other trials, perhaps twice the density. However the smoke was clear and very buoyant.

7. The Weather

Throughout most of the trials the weather was mainly sunny with an unstable boundary layer. Any inversion had dispersed two to three hours before burning commenced. On the windier days the atmosphere would have tended to be more neutral, but always on the unstable side of neutral. On one day a light shower of rain occurred just before and during two of the burns. Otherwise the weather was dry.

No obvious changes in the plume characteristics due to the small changes in stability were observed.

In the burns when rain had just fallen or fell during the burn, the burn rate was markedly reduced, especially when burning against the wind. At times the fire nearly extinguished. As a result of the weak burn, updraughts were low (about 1 metre per second) and except when the wind was very light the plume did not lift off the ground.

8. Conclusion

The work carried out in these idealised experiments has confirmed computer model output (described in Lee (1984)), if only by demonstrating that there appear to be no conditions or straw treatments that fully suppress both smoke and smuts. "Trade offs" have to be made. Vigorous, complete burns, such as along swathes against a wind of force 3, will tend to give the least dense smoke but can carry large smuts a long way. Conversely, weak burns, such as spread straw against a force 1 - 2 wind, will yield non-buoyant smoke that hugs the ground, but the smuts will not be carried very far. Conditions of completion calm would of course be ideal in unstable atmospheric conditions. However in exposed fields, complete calm rarely lasts more than a few minutes. The almost inevitable light and variable winds that occur in such "calm" conditions would be sufficient to generate large quantities of smoke at ground level. The stable atmosphere that usually accompanies calm weather would only enhance the ground level smoke problem.

Without analysing the smoke or smut samples it is impossible to distinguish which burn type is best for reducing both smoke and smuts, the visual observations certainly could not distinguish the cleanest burn. Wide variations in smoke density and probably smut emission, occurred within any one burn.

The quantitative analysis of smoke and smut samples should give a clearer picture, but any definite conclusions must wait until after the full-scale field trials.

9. Reference

M.J. LEE 1984 A first attempt to model straw burning processes - Agricultural Memorandum No 1014. (Unpublished).

Any comments or suggestions on this paper should be referred to the author.

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